Intro to Cognitive Neuroscience

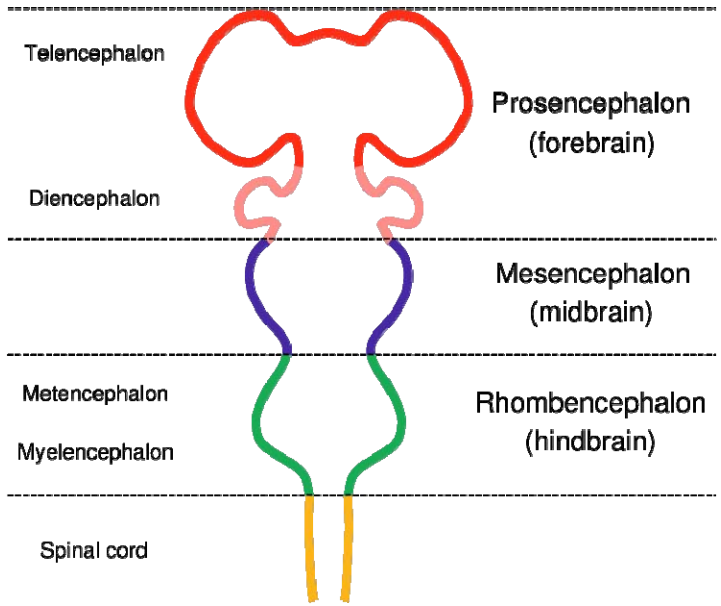
Organization of the brain
Some neurotransmitters

Some anatomical terms

- Dorsal
- Ventral
- Anterior
- Posterior
- Medial
- Lateral

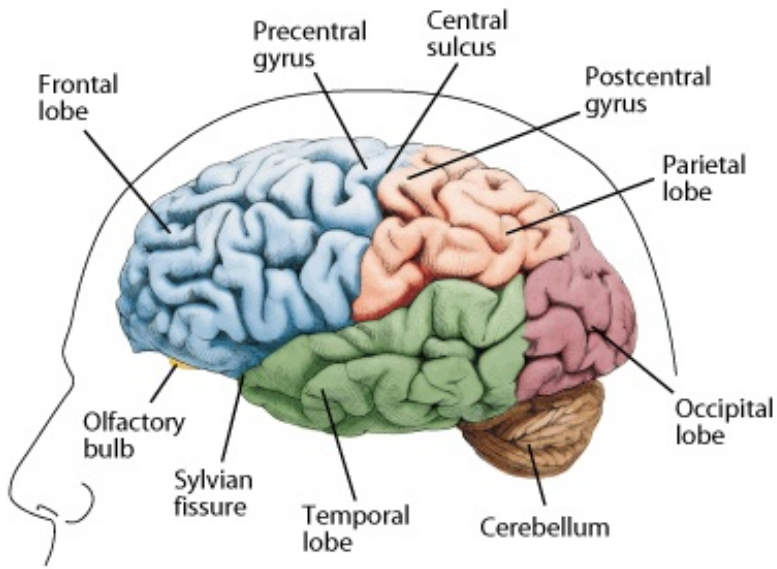
Brain organization labels derive from development

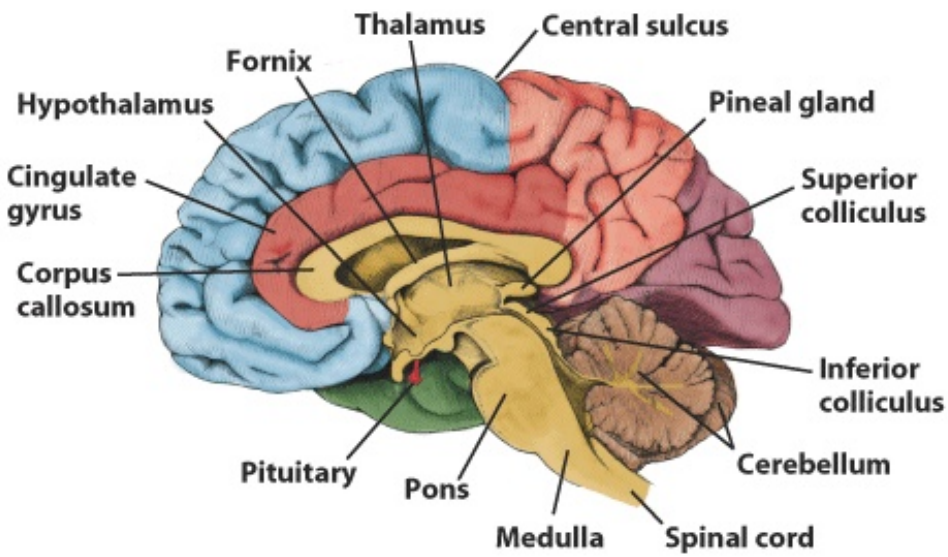
- Neural tube forms three distinct bumps
- Forebrain - most anterior of these
- Hindbrain - most posterior of these
- Midbrain - in-between
- In fully-developed human brain, these distinctions are much harder to see



Forebrain

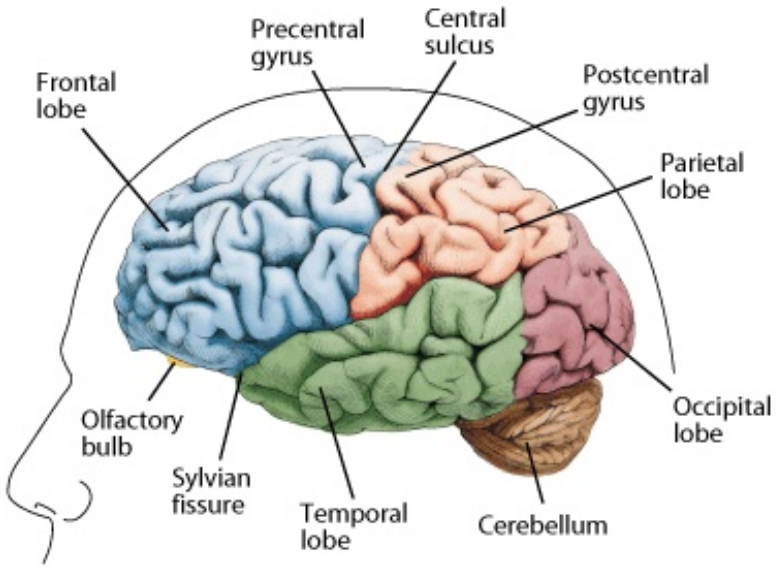
- Divided into cerebral hemispheres (end-brain) and “between-brain” structures
- Cerebral hemispheres (telencephalon)
  - Cerebral cortex and connecting white matter
  - Subcortical: basal ganglia (motor), limbic system (emotion, learning)

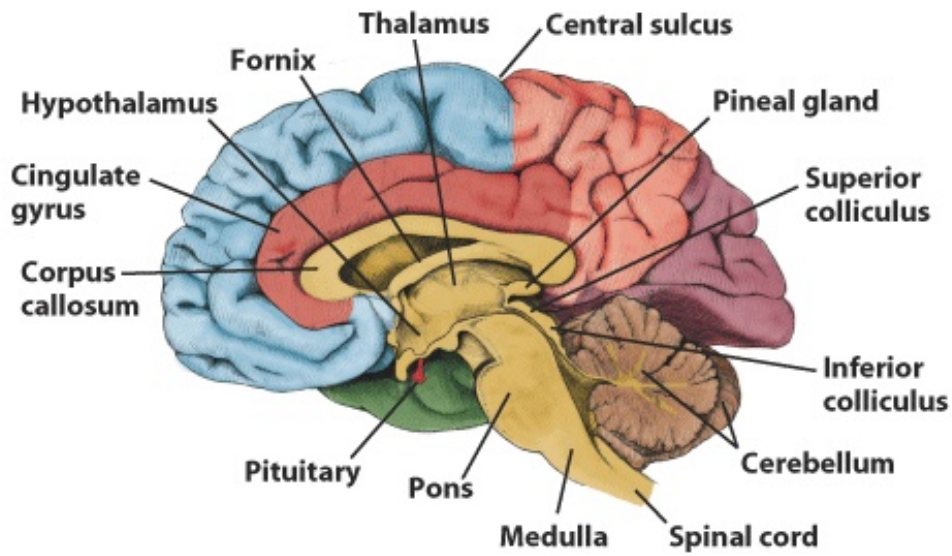




Forebrain

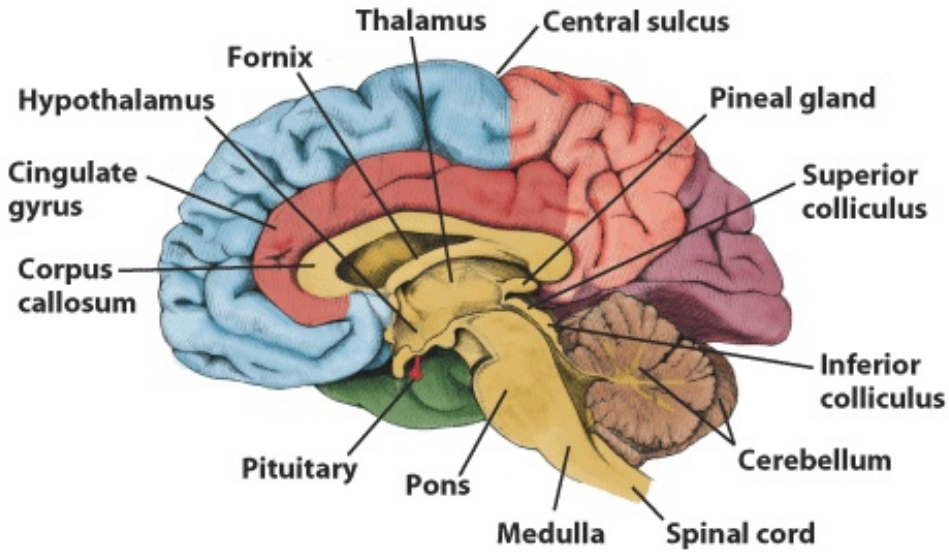
- Divided into cerebral hemispheres (end-brain) and “between-brain” structures
- Between-brain (diencephalon)
  - Thalamus - processes and distributes sensory and motor information
  - Hypothalamus - maintains homeostasis; controls endocrine system; involved in emotional response.

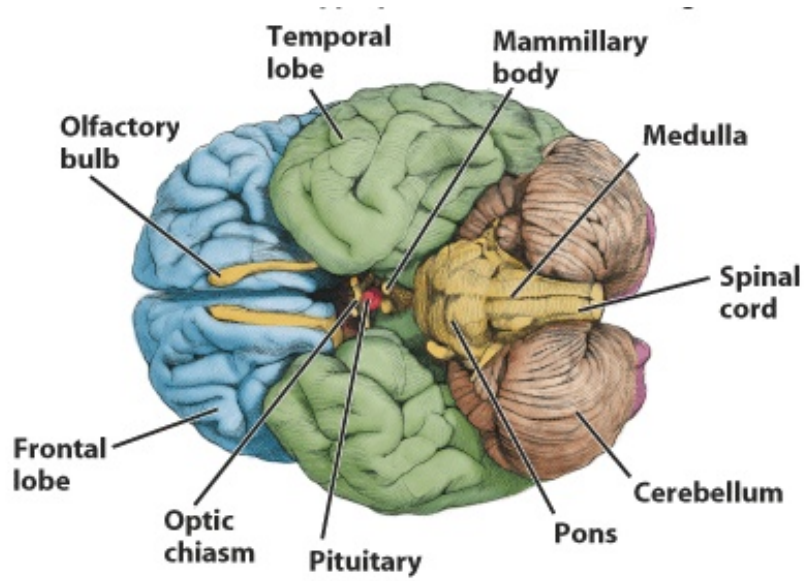




Midbrain

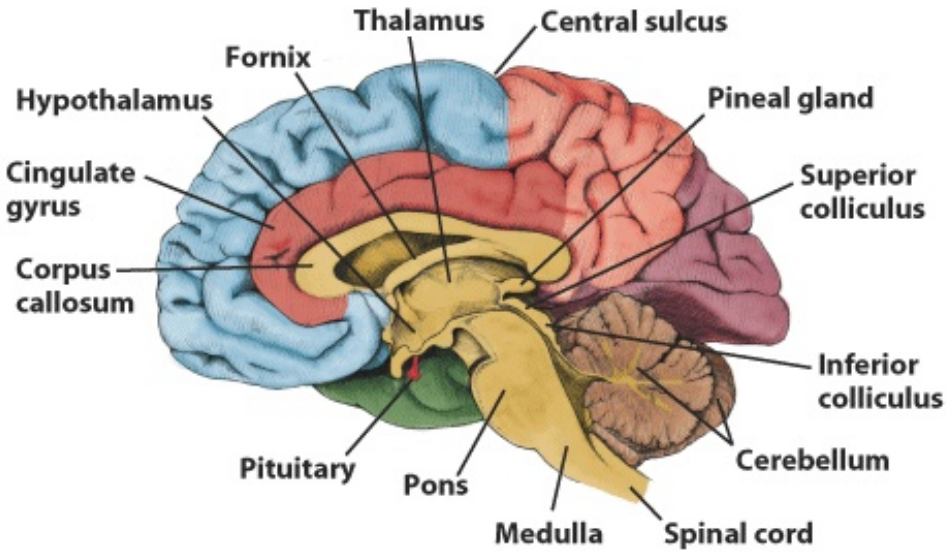
- Tectum - nuclei involved in visual and auditory systems.
- Substantia nigra and ventral tegmental area have large concentrations of dopaminergic cells.

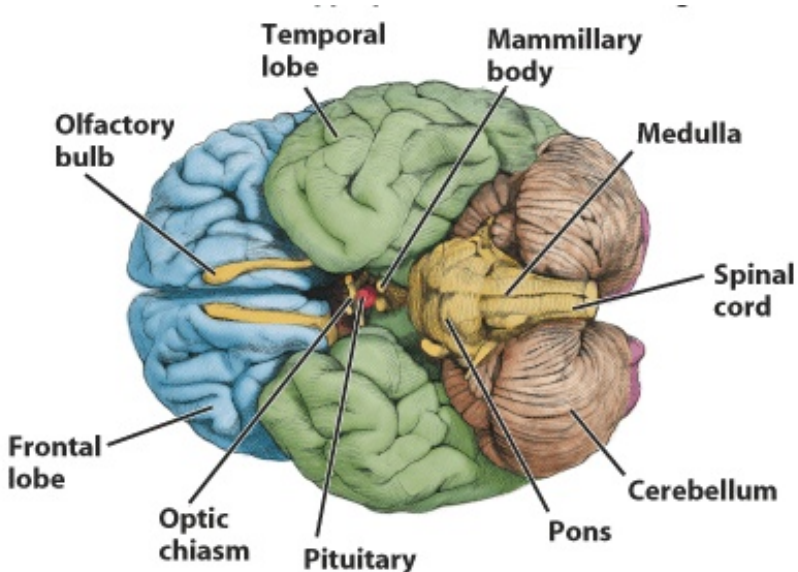




Hindbrain

- Divided into cerebellum, pons, and medulla
- Cerebellum - motor coordination, maintenance of posture
- Pons - alertness, attention, aggression, emotion
- Medulla - vital functions (heart rate, breathing, digestion, blood pressure, etc)





Neurotransmitters

- Criteria for a substance being a neurotransmitter:

1. Exists in presynaptic axon terminals
2. Presynaptic cell contains enzymes for synthesizing substance
3. Substance is released in significant quantities when nerve impulses reach terminals
4. Receptors specific to substance on post-synaptic membrane
5. Application of the substance causes post-synaptic potentials
6. Blocking release of substance prevents pre-synaptic impulses from affecting post-synaptic potentials

Acetylcholine (ACh)

- First NT to be discovered, by Otto Loewi in 1921.
- Experiment design came to him in a dream.
- Showed that nerve stimulation => release of chemical, which affects other cells.
- Loewi called it “Vagusstoff” (vagus-stuff).

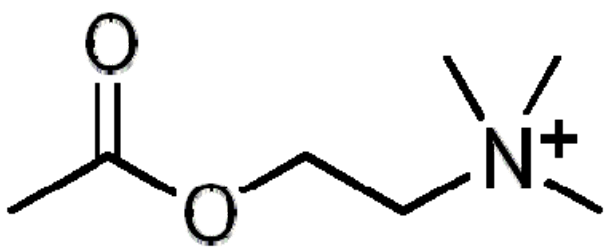
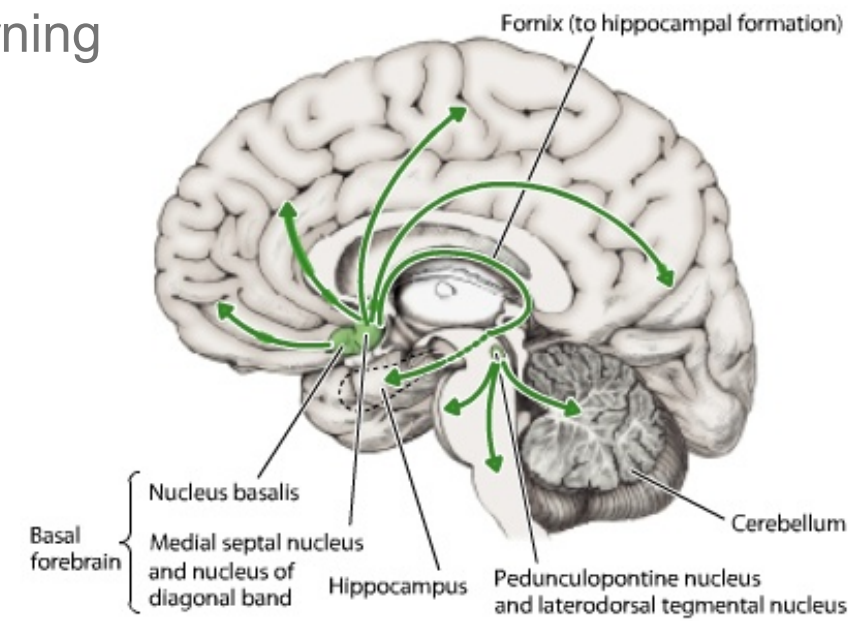


Image courtesy of Taiwan-awei

Acetylcholine

- NT at neuromuscular junction
- In brain, basal forebrain cholinergic system (BFCS) innervates cortex, hippocampus, limbic system.
- Blocking ACh in BCFS interferes with learning tasks.



Acetylcholine - nicotinic receptors

- ACh has two types of receptors
- Nicotinic receptors are ionotropic. Channel for Na^+ and Ca^{2+}, so excitatory.
- Receptor at neuromuscular junction; also some in CNS.
- Also enhance release of NT when located on terminals.

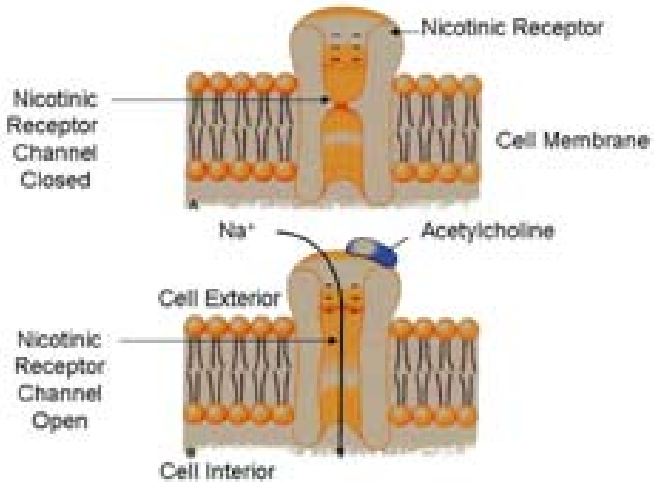
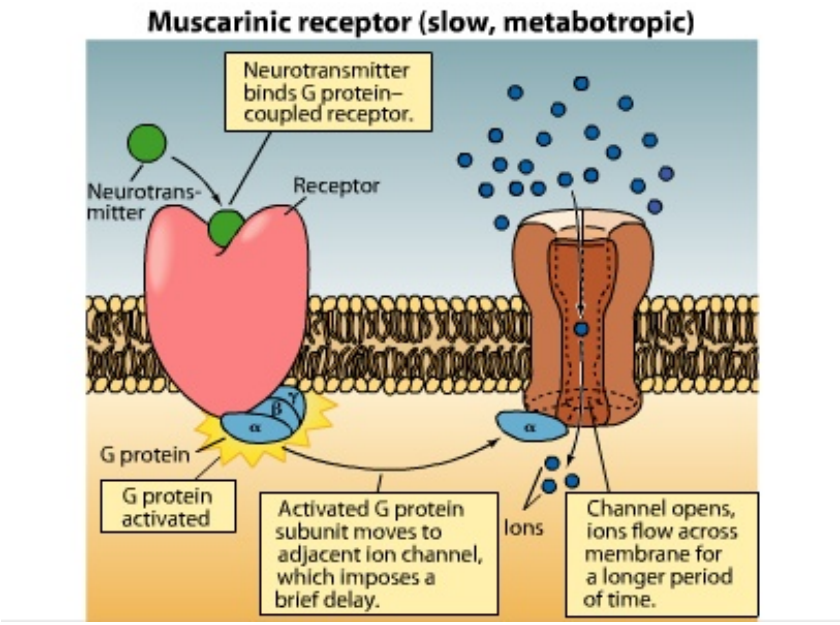


Image courtesy of the Centers for Disease Control.

Acetylcholine - muscarinic receptors

- Muscarinic receptors are metabotropic.

- (Metabotropic receptors cause long-lasting changes in the post-synaptic cell, usually by activating a second-messenger system.)

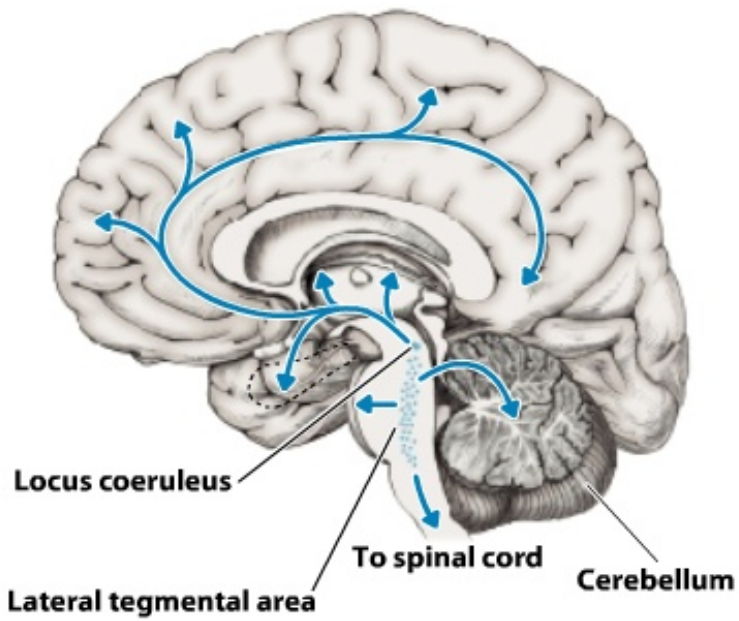


Acetylcholine - muscarinic receptors

- Muscarinic receptors are metabotropic.
- (Metabotropic receptors cause long-lasting changes in the post-synaptic cell, usually by activating a second-messenger system.)
- Cortex, hippocampus, thalamus, striatum, and basal forebrain all have lots of muscarinic receptors.
- Muscarinic receptors are involved in cognitive and motor functions of ACh.

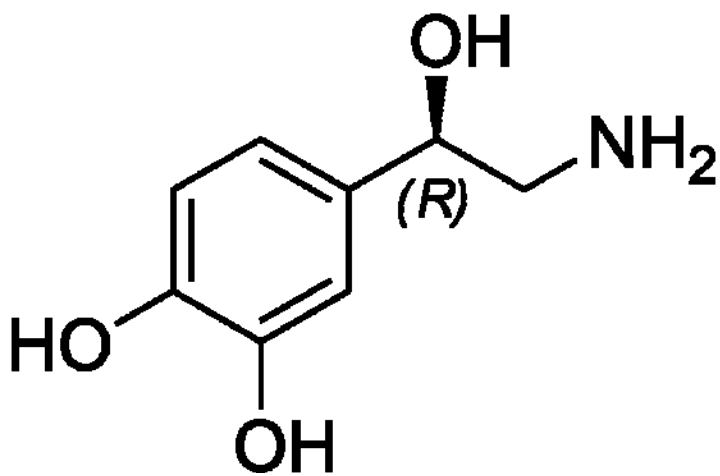
Norepinephrine (NE)
(British: Noradrenaline (NA))

- Noradrenergic cells primarily located in pons and medulla.
- Cells from locus coeruleus in pons project to cortex, limbic system, thalamus, hypothalamus.
- Locus coeruleus cells involved in vigilance - alertness to stimuli.
- NE also acts as a hormone.



Norepinephrine

- Norepinephrine receptors are metabotropic.
- Found in cortex, thalamus, hypothalamus, cerebellum, hippocampus, and amygdala.
- Four types of NE receptors. All activate second-messenger systems to cause changes w/ in the post-synaptic neuron.



Dopamine (DA)

- Dopaminergic cells primarily located in midbrain; two pathways.
  - Nigrostriatal path: cells in substantia nigra project to striatum
  - Mesolimbocortical path: cells in ventral tegmental area project to cortex and to limbic structures.
- Nigrostriatal path involved in motor control
- Mesolimbocortical path involved in reward and addiction

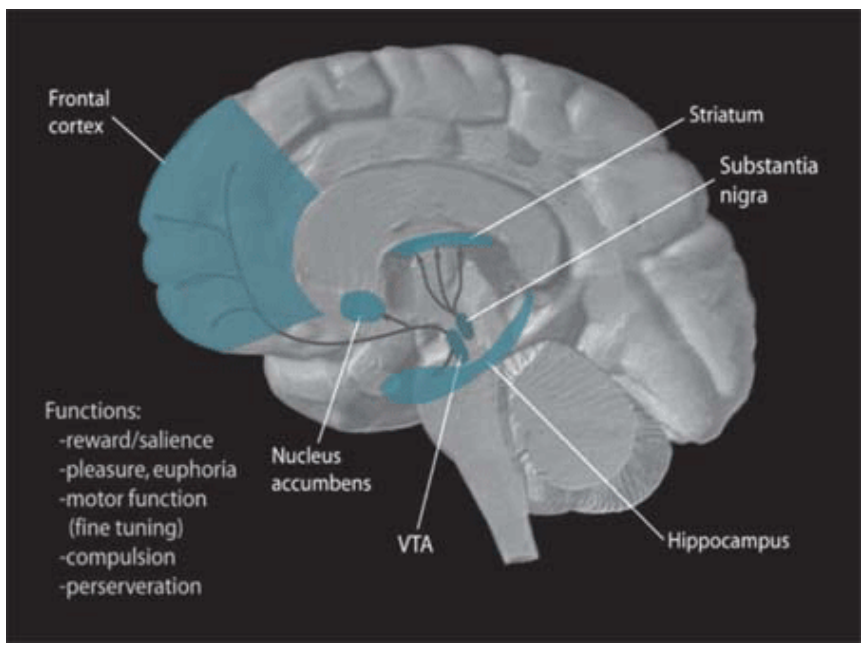
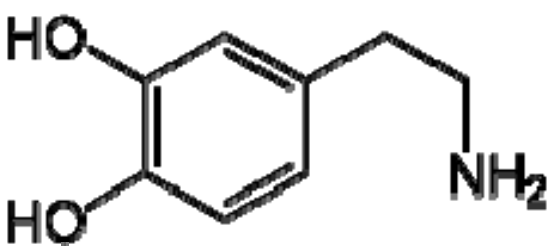


Image courtesy of the National Institutes of Health

Dopamine

- DA receptors are metabotropic
- Five types of DA receptors, classified as D_1-like and D_2-like
- D_1-like cause an increase in cAMP, D_2-like cause a decrease in cAMP
- DA and NE are very chemically similar; both are reuptaken from the synapse by similar transporter proteins.



Serotonin (5-HT)

- Serotonergic cells concentrated in raphe nuclei in brainstem
- Project to cortex, hippocampus, basal ganglia, limbic system
- 5-HT implicated in sleep, mood, anxiety

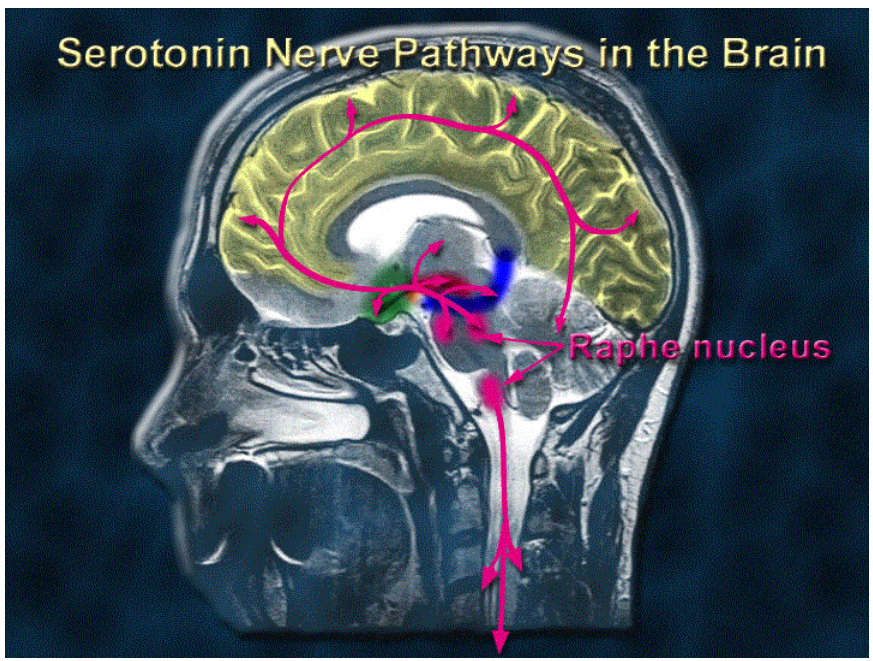


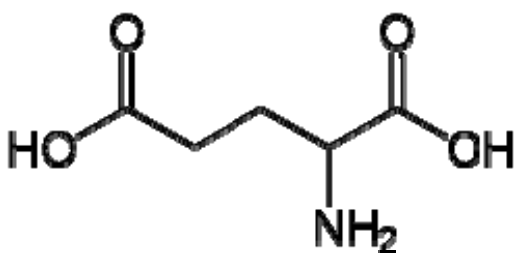
Image courtesy of the National Institutes of Health.

Serotonin

- 5-HT is reuptaken by the 5-HT transporter
    - SSRI antidepressants (like Prozac) block this transporter
- >15 types of 5-HT receptors
- Most are metabotropic (but 5-HT3 receptors are ionotropic and excitatory)

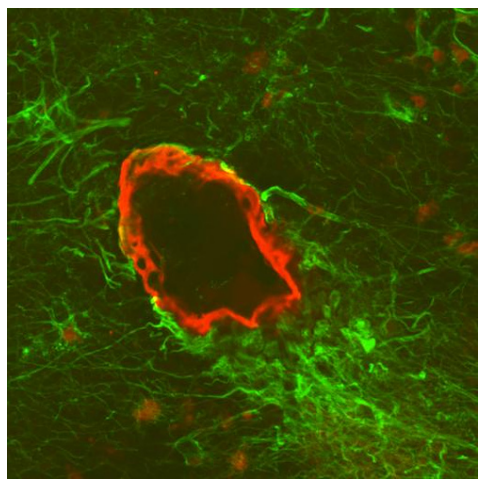
Glutamate

- The transmitter for fast excitatory transmission
- Ionotropic receptor types include AMPA and NMDA
- Metabotropic receptors work by a variety of pathways - inhibit cAMP formation, activate phosphinositide system, inhibit glutamate release.



Glutamate

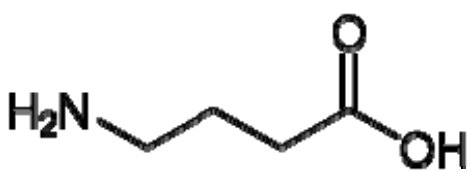
- High levels of glutamate can be toxic to cells.
- So, uptake of extracellular glutamate is important!
- Astrocytes as well as neurons have proteins for glutamate uptake.



A blood vessel covered by astrocytes (in green).
Image courtesy of Zerd.

GABA (γ-aminobutyric acid)

- Workhorse inhibitory transmitter in the brain.
- 10%-40% of nerve terminals in cortx, hippocampus and substantia nigra are GABAergic.
- In cortex and hippocampus, lots of local GABAergic interneurons.
- GABAergic neurons from striatum to substantia nigra are projection neurons



GABA

- $GABA_A$ receptors are ionotropic; allow Cl^- to flow into cell.

- $GABA_B$ receptors are metabotropic inhibit formation of cAMP, stimulate K^+ channels opening.

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